Duct Design

ME 425

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Duct Design

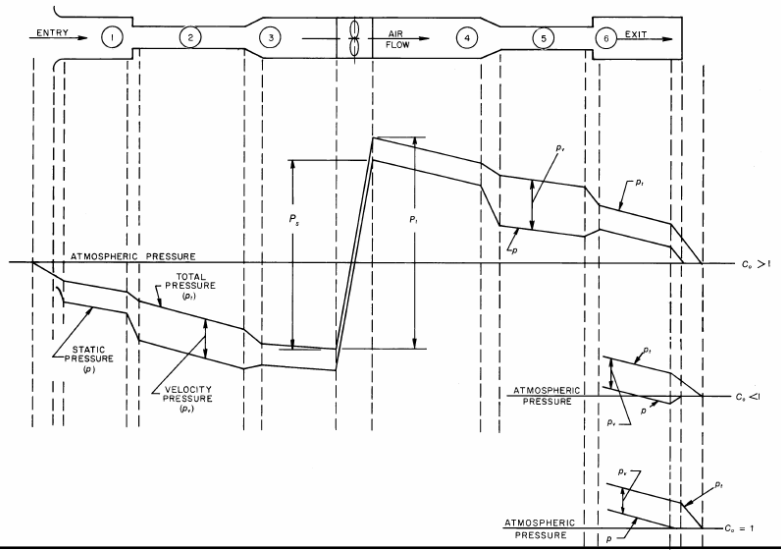
- The purpose of air conditioning ductwork is to deliver air from the fan to the diffusers which distribute the air to the room.
- Air Moves Through the Ductwork in Response to a Pressure Difference Created by the Fan
- The necessary pressure difference will be a function of the way the ductwork is laid out and sized.
- The objective of duct design is to size the duct so as to minimize the pressure drop through the duct, while keeping the size (and cost) of the ductwork to a minimum.
- Proper duct design requires a knowledge of the factors that effect pressure drop and velocity in the duct.

Duct System Pressure

- Total Pressure, TP, is Related to the Energy in the Air Stream, and is equal to:

  TP = Static Pressure + Velocity Pressure
- Static pressure and velocity pressure increase and decrease as the air proceeds through the ductwork, depending on the cross-sectional area of the flow.
- The total pressure of the airstream decreases as the air proceeds through the the ductwork due to the conversion of mechanical energy to heat caused by friction

Duct System Pressure



Velocity Pressure

$$VP = \left(\frac{V}{4005} \right)^2$$

Where:

VP = Velocity Pressure, inches H_2O

V = Velocity, feet per minute

Static Pressure Losses

- Frictional Losses
  - Due to fluid viscosity and turbulence in the flow through the ductwork, and occur along the entire length of the ductwork
- Dynamic Losses
  - Result from flow disturbances caused by fittings that change the airflow direction or area.

Frictional Loss Calculation

- Velocity Reduction Method
  - Velocity at the fan discharge is pre-selected. The duct system is designed to provide progressively lower duct velocities as the air proceeds from the main duct to the branches.
- Static Regain Method
  - The ducts are sized so the increase in static pressure at each take-off offsets the pressure loss of the succeeding section of ductwork.
- Equal Friction Method
  - The duct is sized to result in a constant pressure loss per unit length of duct.

Equal Friction Method

Frictional Losses, Δp, can be approximated:

$$\Delta p = 0.03 f \left(\frac{L}{d^{1.22}} \right) \left(\frac{V}{1000} \right)^{1.82}$$

Rectangular Ductwork is converted to round:

$$D_e = 1.30 \frac{(ab)^{0.625}}{(a+b)^{0.25}}$$

Equal Friction Chart

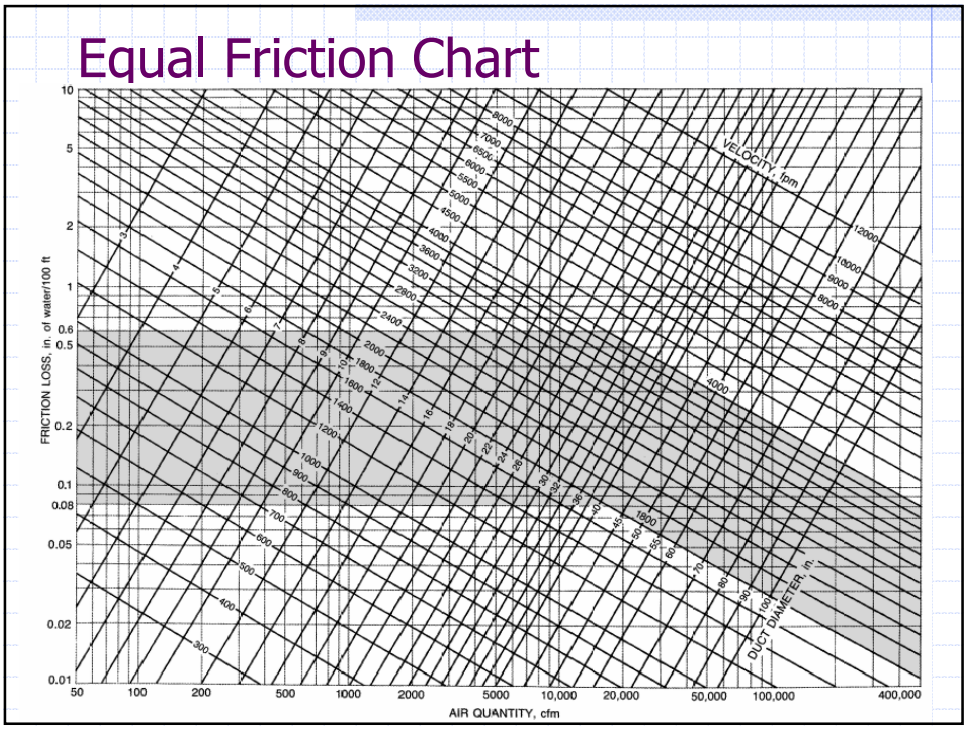


Table 2 Equivalent Rectangular Duct Dimensions

Circular Duct Diameter, in.	Length One Side of Rectangular Duct (*a*), in.													
	4	5	6	7	8	9	10	12	14	16	18	20	22	24
	Length Adjacent Side of Rectangular Duct (*b*), in.													
5	5													
5.5	6	5												
6	8	6												
6.5	9	7	6											
7	11	8	7											
7.5	13	10	8	7										
8	15	11	9	8										
8.5	17	13	10	9										
9	20	15	12	10	8									
9.5	22	17	13	11	9									
10	25	19	15	12	10	9								
10.5	29	21	16	14	12	10								
11	32	23	18	15	13	11	10							
11.5		26	20	17	14	12	11							
12		29	22	18	15	13	12							
12.5		32	24	20	17	15	13							
13		35	27	22	18	16	14	12						
13.5		38	29	24	20	17	15	13						
14			32	26	22	19	17	14						
14.5			35	28	24	20	18	15						
15			38	30	25	22	19	16	14					
16			45	36	30	25	22	18	15					

Maximum Duct Velocity

Application	Controlling Factor Noise Generation Main Ducts	Controlling Factor - Duct Friction			
		Main Ducts		Branch Ducts	
		Supply	Return	Supply	Return
Residences	600	1000	800	600	600
Apartments Hotel Bedrooms Hospital Bedrooms	1000	1500	1300	1200	1000
Private Offices Directors Rooms Libraries	1200	2000	1500	1600	1200
Theatres Auditoriums	800	1300	1100	1000	800
General Offices High Class Restaurants High Class Stores Banks	1500	2000	1500	1600	1200
Average Stores Cafeterias	1800	2000	1500	1600	1200
Industrial	2500	3000	1800	2200	1500

** From Carrier Air System Design Manual*

Approximate Ductwork Cost

Dimension	Gauge*	lb/SF
Up to 12″	26	0.906
13″ to 30″	24	1.156
31″ TO 54″	22	1.406
55″ TO 84″	20	1.656
84″ and Over	18	2.156

Galvanized Steel = $8.25 per lb**

* Source: Uniform Mechanical Code
** Source: Recent bids – includes fittings & everything

Economical Duct Design

- Minimize aspect ratio (a/b)
- Minimize total pounds of sheet metal and
- Minimize number of reductions (2-inch rule)

CHART 5—OPERATING COST VS ASPECT RATIO

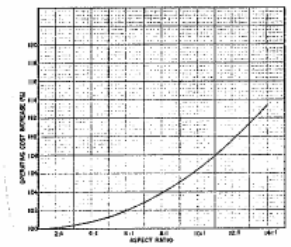
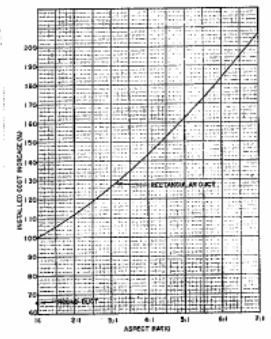


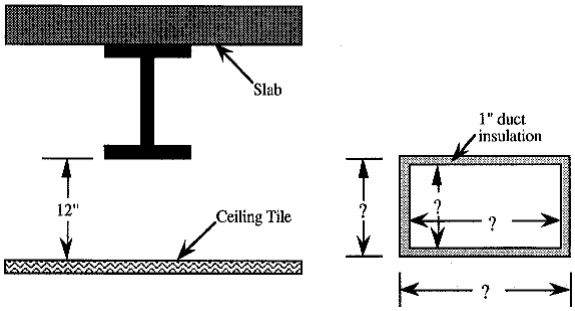
CHART 4—INSTALLED COST VS ASPECT RATIO



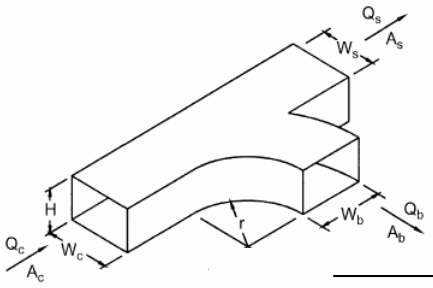
Duct Sizing Exercise

An office space has a sensible peak cooling load of 29,400 Btu/hr. The inside design temperature is 78 °F and the supply air temperature is 60°F. The duct must be lined and yet fit under the beam shown below and not exceed a friction loss of 0.10 inches per 100 feet.

Determine the most economical duct size.



Dynamic Loss Calculation



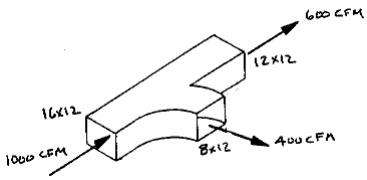
$$\Delta p_f = C_o p_{v,o}$$

$r/W_b = 1.0$
$A_s = A_b \geq A_c$

C_b Values

A_s/A_c	A_b/A_c	Q_b/Q_c = 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.50	0.25	3.44	0.70	0.30	0.20	0.17	0.16	0.16	0.17	0.18
	0.50	11.00	2.37	1.06	0.64	0.52	0.47	0.47	0.47	0.48
	1.00	60.00	13.00	4.78	2.06	0.96	0.47	0.31	0.27	0.26
0.75	0.25	2.19	0.55	0.35	0.31	0.33	0.35	0.36	0.37	0.39
	0.50	13.00	2.50	0.89	0.47	0.34	0.31	0.32	0.36	0.43
	1.00	70.00	15.00	5.67	2.62	1.36	0.78	0.53	0.41	0.36
1.00	0.25	3.44	0.78	0.42	0.33	0.30	0.31	0.40	0.42	0.46
	0.50	15.50	3.00	1.11	0.62	0.48	0.42	0.40	0.42	0.46
	1.00	67.00	13.75	5.11	2.31	1.28	0.81	0.59	0.47	0.46

Fitting Loss Exercise



1000 CFM is flowing through a 16 x 12 rectangular duct. 400 CFM flows through an 8 x 12 branch to another room, and the remaining 600 CFM continues along the 12 x 12 main duct.

What is the pressure drop, in inches of water, through the branch?

Homework

- Read 05F35.1-25
- The ductwork shown below will serve several open office spaces. Size the ductwork and calculate the maximum pressure drop. The maximum vertical space is 12 inches and the branch fittings are of the same type as the example in the handout.